# Estimate for Energy Economy Ratios for Consideration of On-Road and Off-Road Motorcycles in the Low Carbon Fuels Standard Program

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California Air Resources Board (CARB) Monitoring and Laboratory Division staff conducted this analysis to determine the Energy Economy Ratios (EERs) for on-road and off-road motorcycles for use in the Low Carbon Fuels Standard (LCFS) program. Due to limited availability of data, staff was only able to make a conservative EER estimate of 4.4 for on-road motorcycles and 3.3 for off-road motorcycles.

*What is an EER?*

An EER is a dimensionless value that represents the efficiency of a fuel as used in a powertrain as compared to a reference fuel. EERs are often a comparison of miles per gasoline gallon equivalent (MPGe) between two fuels. In this case, the EER represents a comparison between electric motorcycles and their gasoline internal combustion engine (ICE) counterparts. In the LCFS Program, EERs are used in calculations to generate credits. Higher EERs will result in more credits generated.

*Data Sources*

Manufacturers of electric on-road and dual sport motorcycles submitted MPGe data generated using the Urban Dynamometer Driving Schedule (UDDS). Also included was data for one off-road motorcycle using the World Motorcycle Test Cycle (WMTC), including miles per gallon of gasoline (MPG) data for its equivalent ICE counterpart. To determine MPG for comparable on-road and dual sport motorcycles, staff referred to the United States Environmental Agency's (U.S. EPA) on-road motorcycle emissions certification data generated using the UDDS. U.S. EPA motorcycle emissions data is available at: https://www.epa.gov/sites/production/files/2017-03/2018-mc-ctrr.xls.

*Methodology*

Staff calculated UDDS MPG for comparable ICE motorcycles from the U.S. EPA emissions data set. Comparable ICE motorcycles were defined as those having a power rating within approximately ± 10% of the electric motorcycle being considered. EERs were determined for each electric motorcycle by taking the ratio of UDDS generated MPGe over MPG. Average EERs were then calculated for both on-road and off-road motorcycles. Table 1 lists the MPGe, MPG of comparable ICE motorcycles, and EER for each of the electric motorcycles included in this evaluation. Due to the limited sample size of off-road motorcycles, dual sport vehicles were used in both on-road and off-road calculations.

Table 1. Motorcycle Data for Calculating EERs

| | On-Road / Off-Road | Power (KW) | MPGe UDDS | MPGe Highway | Avg. MPG UDDS (comparable ICE) | EER |
|---|---|---|---|---|---|---|
| Bike A[1] | Off-Road | 16 | 381 | - | 78.4 | 4.86 |
| Bike B | Both | 20 | 485 | 205 | 68.8 | 7.05 |
| Bike C[2] | Both | 25 | 475 | 225 | 61.0 | 7.79 |
| Bike D | On-Road | 33 | 485 | 205 | 53.6 | 9.04 |
| Bike E[2] | On-Road | 40 | 453 | 225 | 54.5 | 8.32 |
| Bike F[2] | On-Road | 45 | 457 | 225 | 53.6 | 8.51 |
| Bike G | On-Road | 50 | 476 | 240 | 44.0 | 10.81 |
| Bike H | On-Road | 52 | 476 | 240 | 44.5 | 10.69 |

[1]Off-road motorcycle with data derived using WMTC.

[2]Composite MPGe of multiple bikes with the same power rating.

Initial Staff estimate of average EERs:

- On-Road Motorcycle EER: 8.89
- Off-Road Motorcycle EER: 6.57

A truly representative EER would be based on MPGe and MPG data collected over multiple drive cycles representing real world operating conditions. However, only emissions data derived from the UDDS was available to staff to calculate ICE motorcycle MPG. Data in Table 1 shows that highway MPGe is approximately one-half of the UDDS MPGe, meaning staff's initial EERs may be higher than a truly representative EER that is based on real world usage. To account for the difference between UDDS MPGe and the actual MPGe that is likely to be achieved in real world usage, staff multiplied the initial EERs by a factor of 0.5. This results in more conservative EER values, which staff recommends should be used until such time that a more comprehensive data set of motorcycle MPG and MPGe under various operating conditions can be collected and analyzed.

Final Staff estimate of average EERs:

- On-Road Motorcycle EER: 4.4
- Off-Road Motorcycle EER: 3.3

CARB staff encourages industry stakeholders to use their expertise and resources to generate and submit additional MPGe data for electric motorcycles, along with MPG data for comparable ICE motorcycles operated under a wide variety of real-world conditions. Staff will evaluate additional data when it becomes available, and will consider amending the on-road and off-road motorcycle EERs if such action is supported by a more robust data set than what was available in the above analysis. Please contact Mr. Jason McPhee at jason.mcphee@arb.ca.gov or (916) 323-1104 if you can provide additional data or have questions about this analysis.